EIGHTH ANNUAL WATER CONSERVATION SHOWCASE

March 22nd • PG&E Pacific Energy Center, San Francisco

USGBC NORTHERN CALIFORNIA

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Advancements in Residential Water Metering Technology

Arthur Burns, Sensus USA

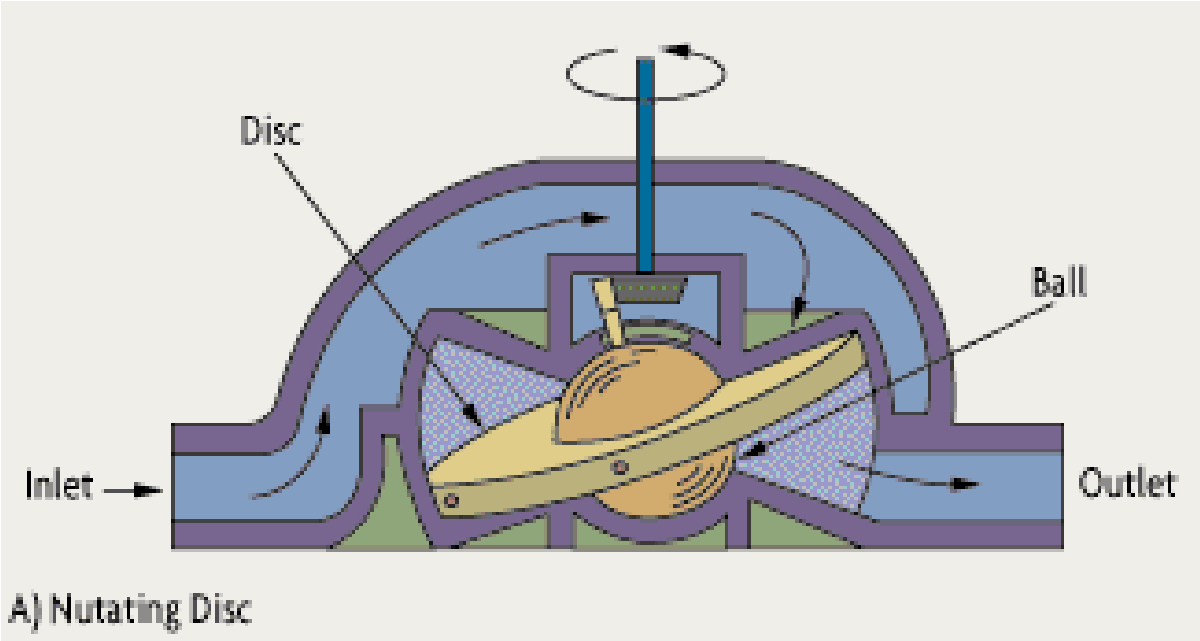
Overview

- Mechanical Water Meter Technology
  - Types
  - Performance Limitations
  - Effects of Wear
- New Solid-State Water Meter Technology
  - Benefits
  - 3 Different Types of Technology
  - Applications

Traditional Mechanical Meters

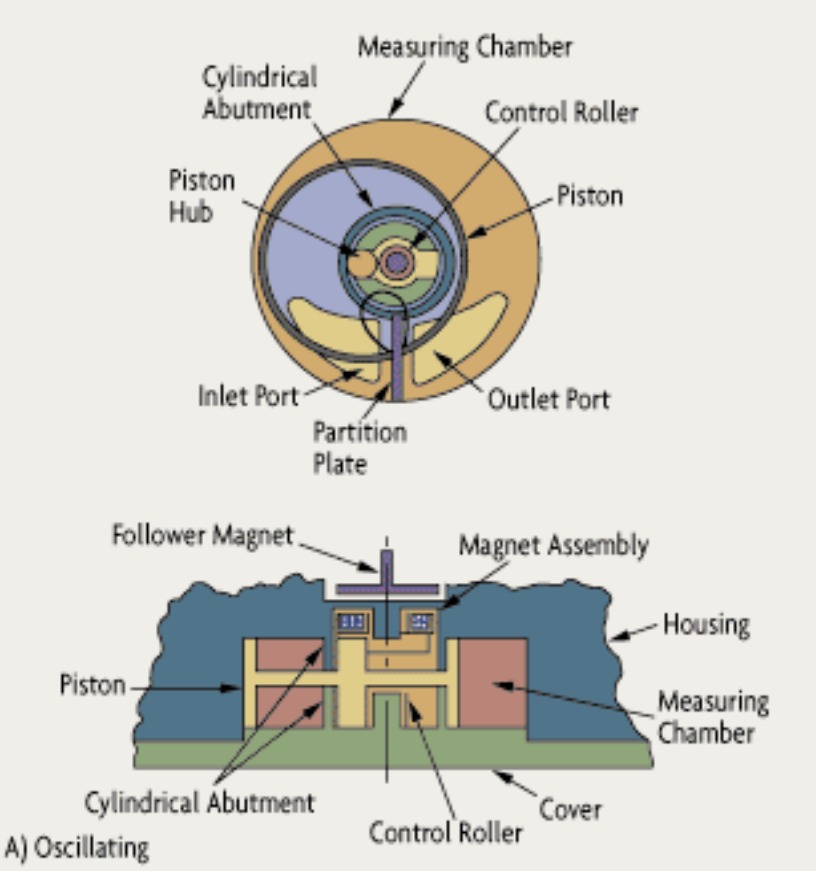
- Positive Displacement
  - Oscillating Piston
  - Nutating Disc
- Velocity
  - Multi-Jet
  - Single Jet

Nutating Disc



Source: OMEGA Complete Flow and Level Measurement Handbook and Encyclopedia®, OMEGA Press, 1995.

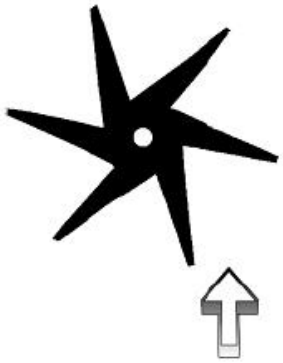
Oscillating Piston



Source: OMEGA Complete Flow and Level Measurement Handbook and Encyclopedia®, OMEGA Press, 1995.

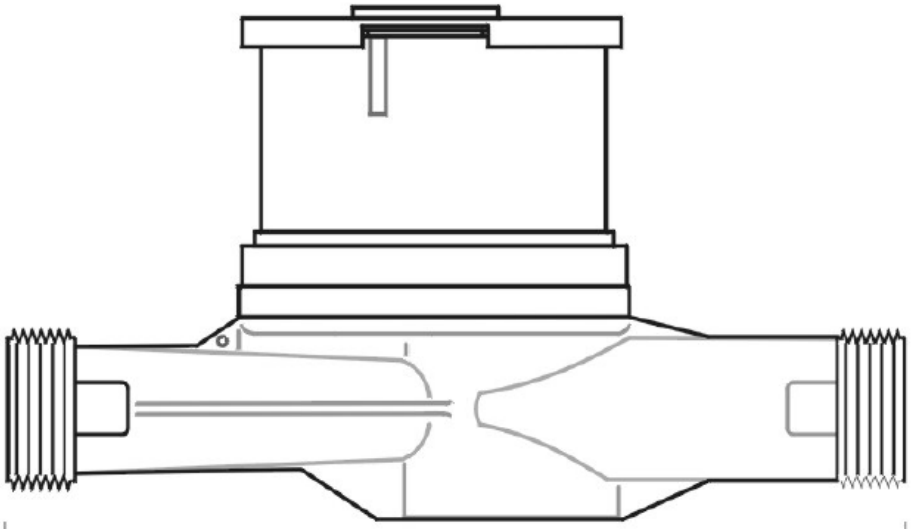
Single Jet Meters

- Water Enters Single Inlet Port
- Small Aperature and Impeller



Single-Jet Impeller

Source: Metron Farnier



Source: Metron Farnier

Multi-Jet Meters

- Water Uniformly Spread Across Multiple Inlet Ports
- Flows across an impeller
- Impeller velocity determines flow rate
- Register determines volume

Benefits of Mechanical Meters

- Proven Technology
- Widely Accepted and Trusted in the Industry
- Technology has Evolved and Improved Over more than 100 Years
- Several Types Can Be Rebuilt - Extending their Useful Life

Disadvantages of Mechanical Meters

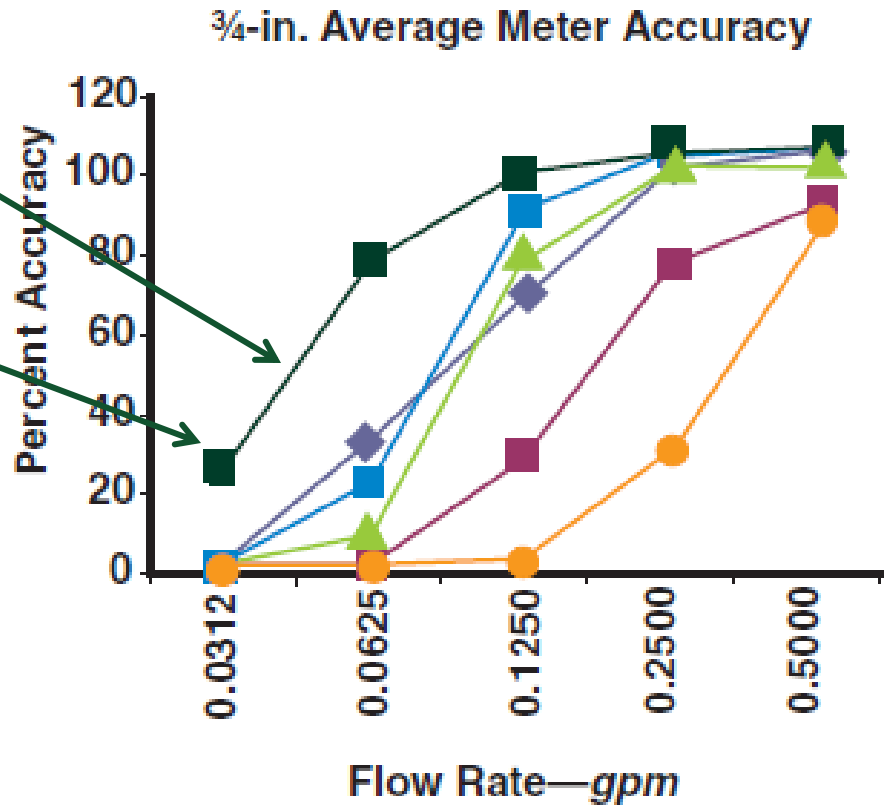
- Inherent Low Flow Performance Limitations
- Accuracy Relies on Close Tolerances that are Subject to Wear
- Particulates in Water Can Cause Problems
- Calcium in Water Can Cause Problems
- Maintenance Can Be Required
- Significant Pressure Loss
- Correct Sizing is Very Important

¾” Mechanical Meter Accuracy at Low Flows

No Meters Registered More than 50% of Flow at 0.06 GPM

No Meters Registered More than 25% of Flow at 0.03 GPM

Actual New Meter Performance Measured by an Independent Laboratory



Source: Apparent Losses Caused By Meter Inaccuracies at Ultralow Flows, Richards et.al, AWWA Journal, June 2010

Implications for Water Conservation

- You Can't Count What You Can't Measure

- Even the Best AMI System Can't Detect Leaks Below a Meter's Lowest Flow Sensitivity
- A Leak of 0.05 GPM (1/20th GPM) amounts to 39 Teaspoons, or about 0.8 Cups per Minute
- This is Not Just a "Drip" Every Few Minutes

Slow Leak?

- 0.05 GPM is **2,160 Gallons** over 30 Days, or **25,920 Gallons** per Year from **ONE** meter
- Across 10,000 Meters, this could amount to **259,200,000 Gallons** per Year (795 Acre Feet)
- How Many Meters Have Leaks at or Below 0.05 GPM?

WE DON'T REALLY KNOW BECAUSE THE MECHANICAL METERS CANNOT MEASURE THESE FLOWS – EVEN WHEN NEW!

What We Do Know

- AWWA States That 16% of a Meter's Usage Occurs at Low Flows (Less Than 1 GPM)
- Mechanical Meters Measure Only A Small Percentage of Flow Below 1/4 GPM – Even When New
- [Unmeasured Flow] Results in Significant Revenue Loss for the Utility

Source: Apparent Losses Caused By Meter Inaccuracies at Ultralow Flows, Richards et.al, AWWA Journal, June 2010

Sources of Non-Revenue Water

AWWA Standard Water Balance

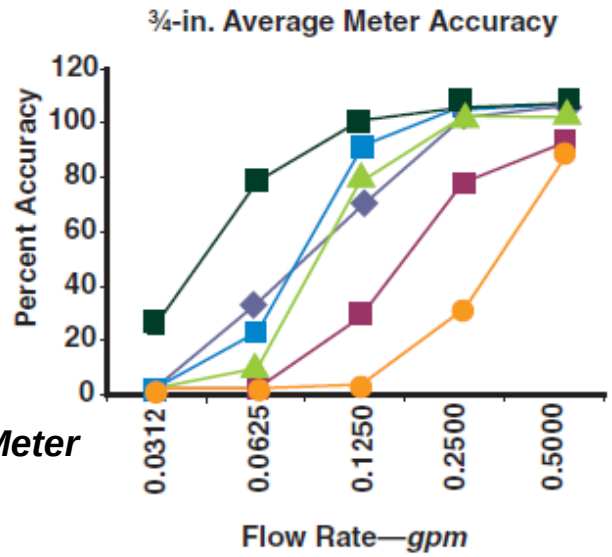
<table>
<tr><td rowspan="6">System Input
(Corrected)</td><td rowspan="4">Authorized Consumption</td><td rowspan="3">Billed Authorized Consumption</td><td>Billed Water Exported</td><td rowspan="3">Revenue Water</td></tr>
<tr><td>Billed Metered Authorized Consumption</td></tr>
<tr><td>Billed Un-metered Authorized Consumption</td></tr>
<tr><td rowspan="3">Un-billed Authorized Consumption</td><td>Un-billed Metered Authorized Consumption</td><td rowspan="5">Non-Revenue Water</td></tr>
<tr><td>Un-billed Un-metered Authorized Consumption</td></tr>
<tr><td rowspan="3">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Use (including theft of water)</td></tr>
<tr><td>Consumption Meter Error</td></tr>
<tr><td colspan="2">Real Losses</td></tr>
</table>

Souce: AWWA

Apparent Losses From Meters

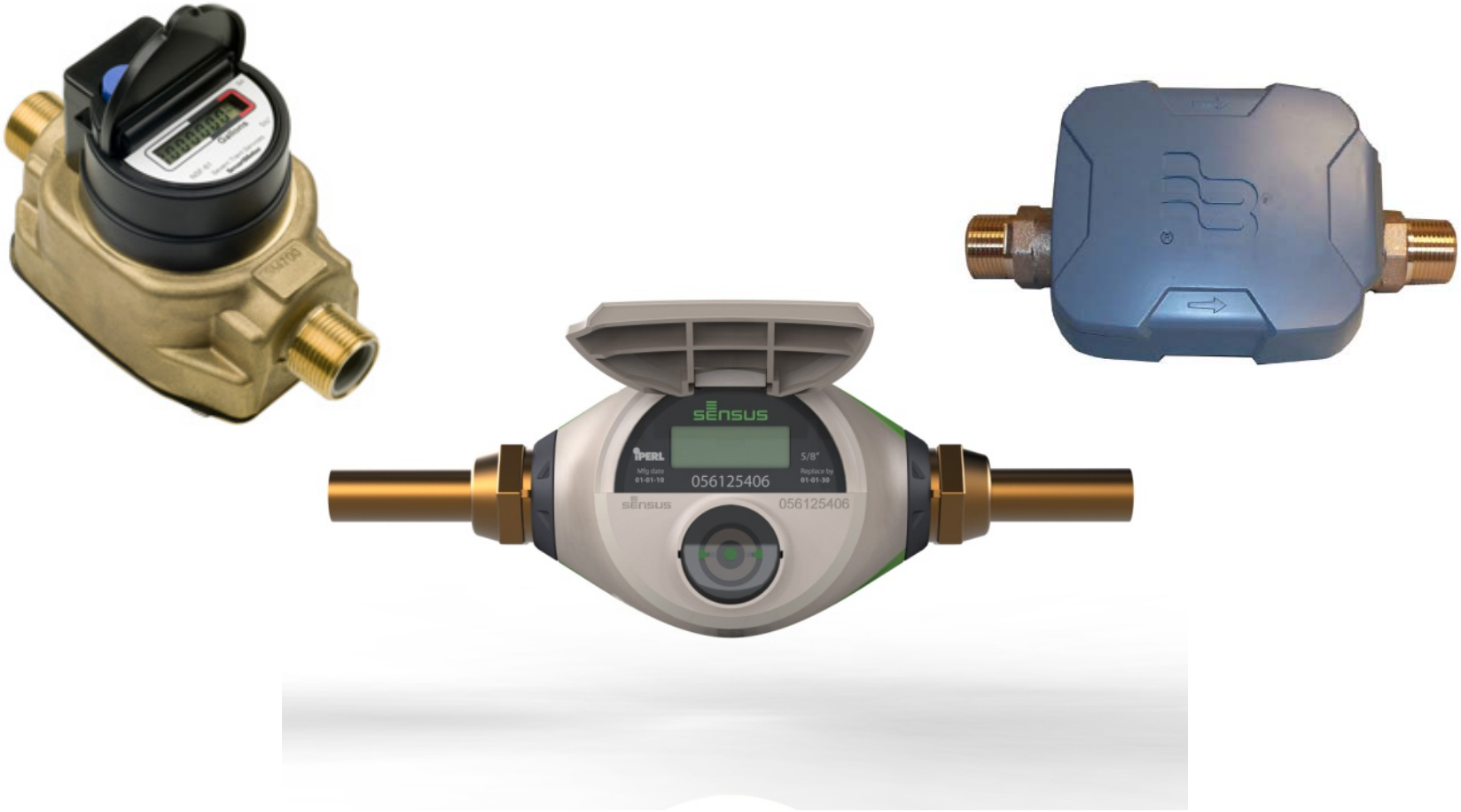
- Based on test studies of anonymous water utilities, typical average customer meter under registration is about 5 to 6 percent.

Source: Thornton, J., Strum, R. and G. Kunkel. ***Water Loss Control****, McGraw-Hill, New York 2008*



Graph Source: ***Apparent Losses Caused By Meter Inaccuracies at Ultralow Flows****, Richards et.al, AWWA Journal, June 2010*

Solid State Meter Technology



3 Different Types of Technology

- Meter Manufacturers Have Responded to Changing Needs By Developing New Residential Meter Technologies:
  - Fluidic Oscillator

  - Residential Ultrasonic

  - Residential Magnetic

Benefits of Solid State Technology

- **Generally, These Technologies Share the Following Traits:**
  - No Moving Parts to Wear Out
  - Particles Do Not Cause Meters to Stick or Stop
  - Reduced Pressure Loss
  - No Maintenance
  - Better Low Flow Accuracy
  - Better High Flow Durability

Fluidic Oscillator Technology From Elster Metering – SM700

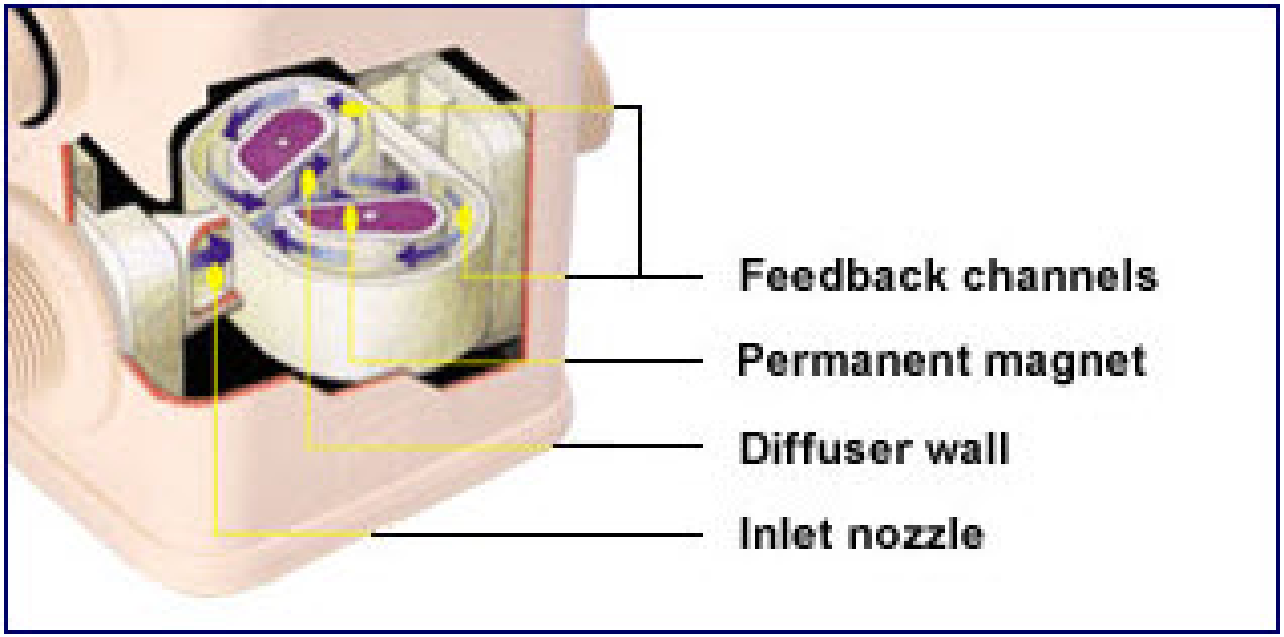
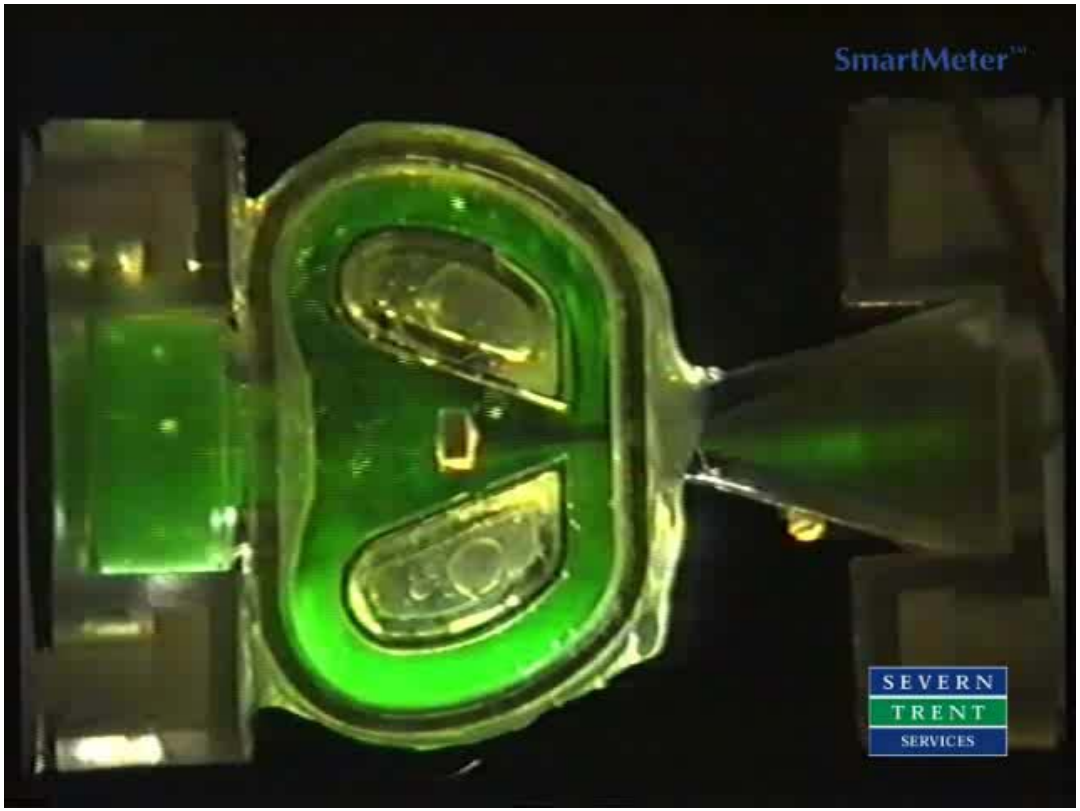


Diagram: Elster Metering

Elster SM700 in Action



Source: Elster Metering

Fluidic Oscillator Theory

- Meter Design Generates Oscillations
- Electrodes Count Oscillations
- Higher Flow Rate = More Oscillations per Time Period

Residential Ultrasonic Technology from Badger Meter – E Series

Ultrasonic Meter Theory

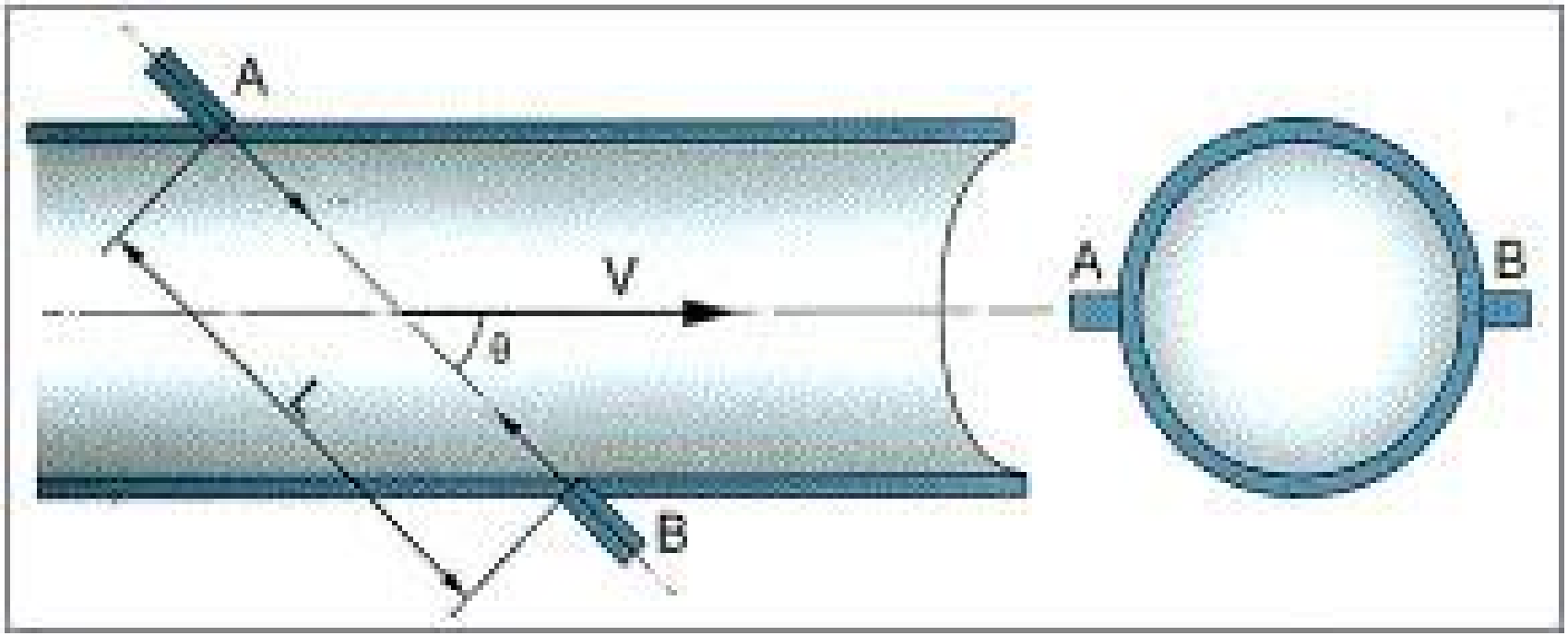
Ultrasonic flow meters measure the difference of the transit time of ultrasonic pulses propagating with and against flow direction. This time difference is a measure for the average velocity of the fluid along the path of the ultrasonic beam. By using the absolute transit times both the averaged fluid velocity and the speed of sound can be calculated. Using the two transit times t_{up} and t_{down} and the distance between receiving and transmitting transducers L and the inclination angle α one can write the equations:

$$v = \frac{L}{2\ \sin(\alpha)}\ \frac{t_{up} - t_{down}}{t_{up}\ t_{down}} \qquad c = \frac{L}{2}\ \frac{t_{up} + t_{down}}{t_{up}\ t_{down}}$$

Ultrasonic Meter Measurement Calculation

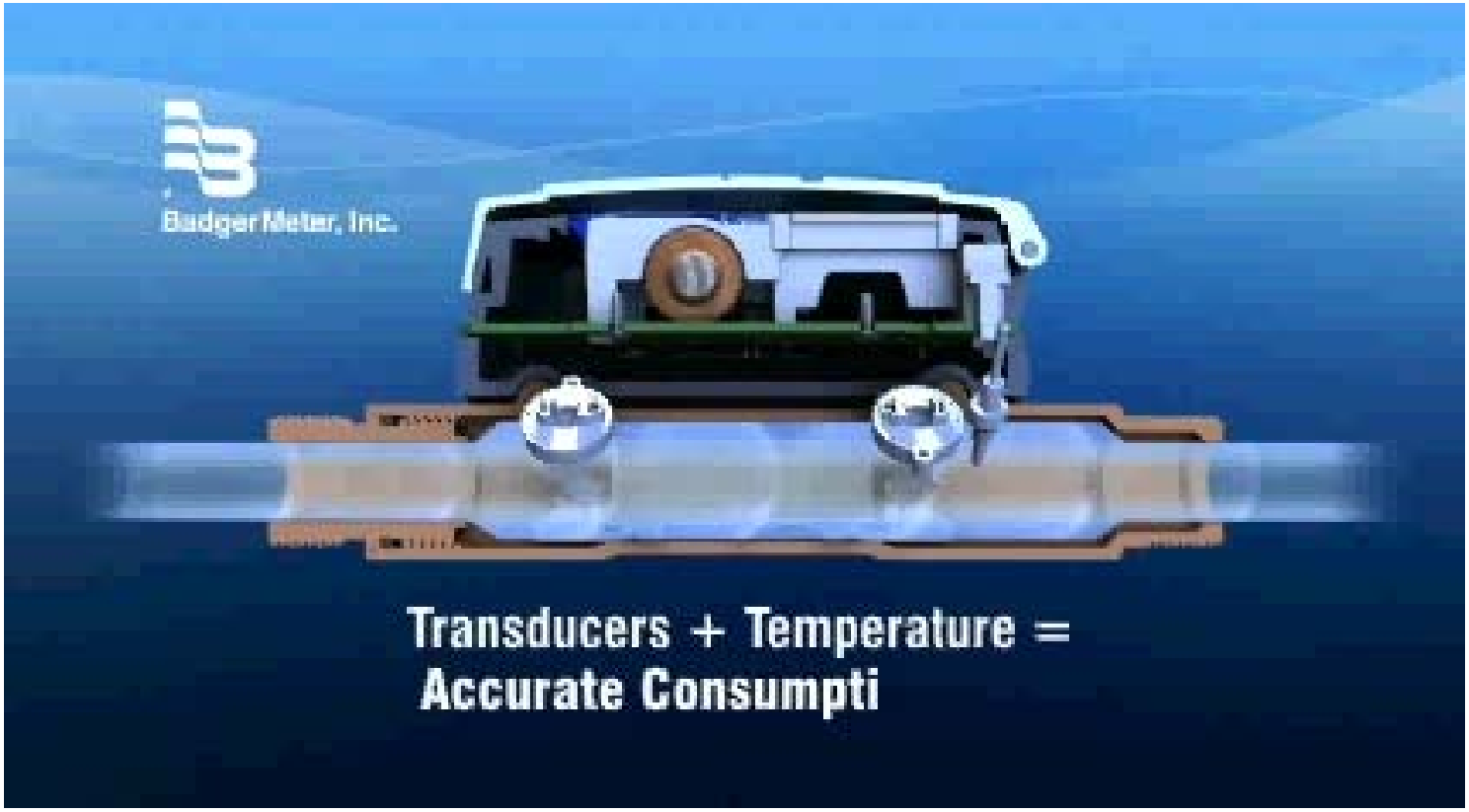
Source: Wikipedia

Typical Ultrasonic Meter Diagram



Source: Shenitech.com

Badger E-Series in Action



Source: Badger Meter

Challenges for Ultrasonic Technology

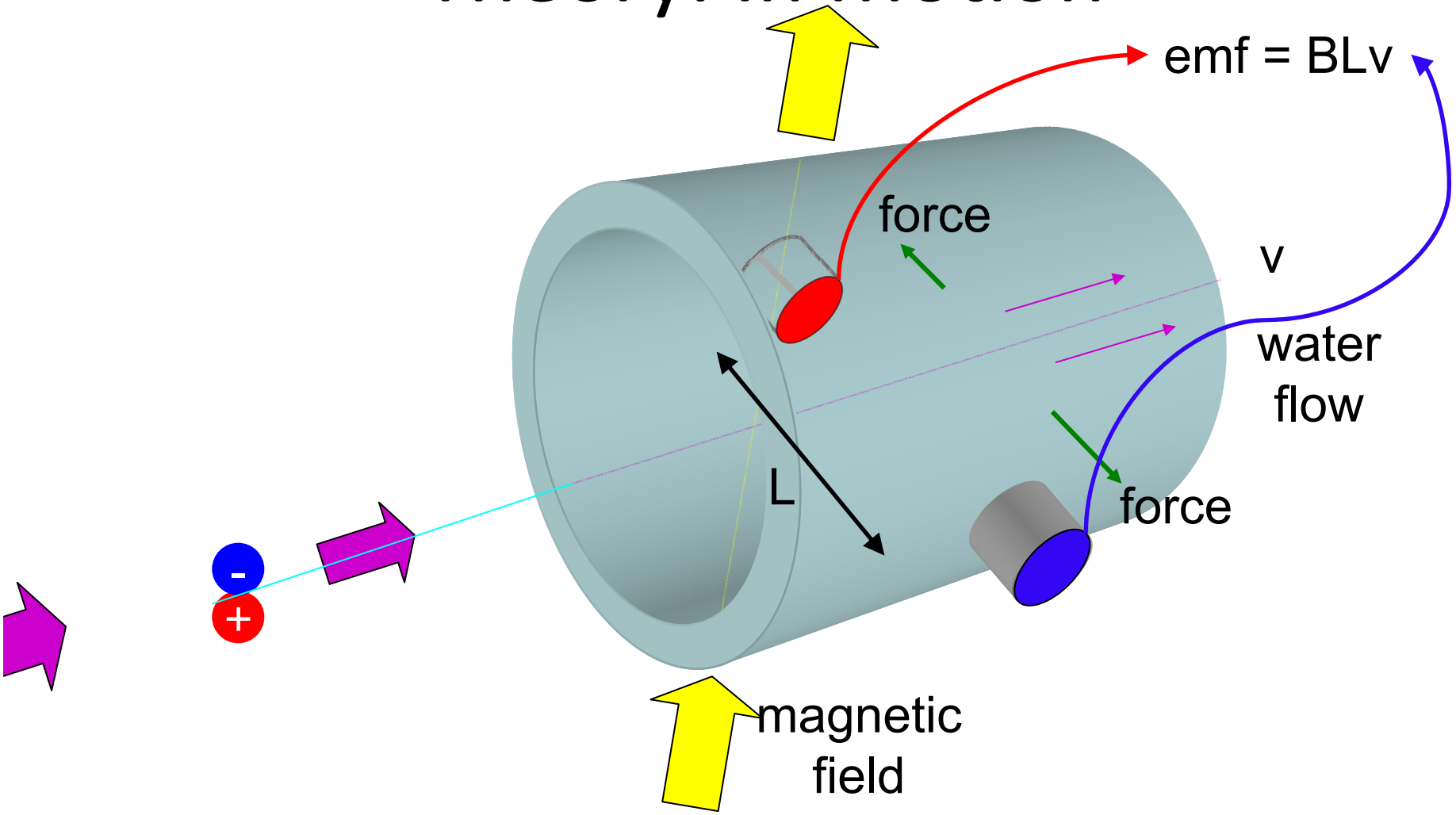
- Requires Power to Generate Sound
- Low Flow and Combination Flow Accuracy Requires High Sample Rate
- No Way to Generate Sound Without Using Power

Residential Magnetic Technology from Sensus USA - iPERL

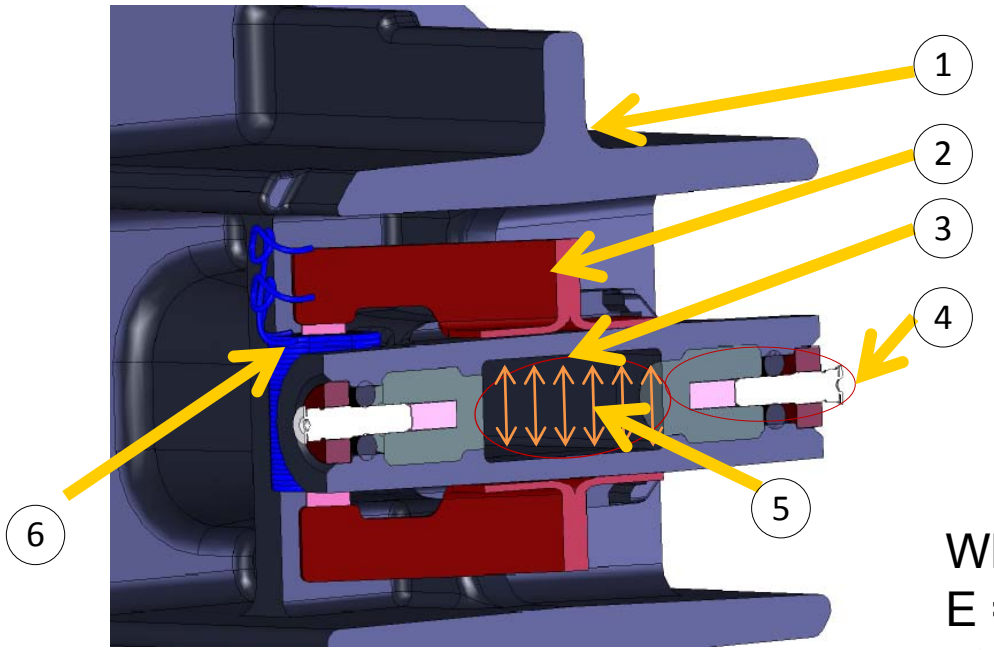
Magnetic Meter Theory

- Uses Faraday's Law of Electromagnetic Induction
- A Magnetic Field is Applied to the Flow Tube
- Electrodes Measure Voltage Across the Field
- The Water Flow Rate Changes the Voltage Across the Field - Faster Flow Equals Higher Voltages
- Periodically "Flip" Field to Increase Accuracy

Electro Motive Force (emf) Theory: In Motion



EMF Theory: iPERL Measurement



1. Flowtube
2. Pole piece
3. Measurement chamber
4. Electrode
5. Magnetic field
6. Magnetic drive coil

$$E = B \cdot L \cdot v$$

(Magnetic Flow Meter Principle)

Where:
E = Electro-motive Force (Voltage) induced at the electrodes
B = Magnetic field (magnetic flux density) generated by drive coil and pole pieces.
V = Velocity of water flow crossing measurement area
L = Distance between two pole pieces.

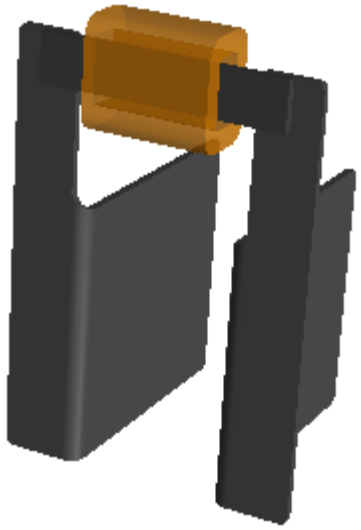
Challenges for Magnetic Technology

- Can Measure Continuously but Typically Must Use Lots of Power to Keep Magnetic Field Active
- Electromagnets Traditionally Used to Generate Field Required Lots of Power
- Noisy Electrodes = Bad Signal to Noise Ratio
- Low Flow and Combination Flow Accuracy Requires High Sample Rate

Remanence: What and Why?

- Definition: “The magnetization left behind in a material after the external magnetic field is removed”
- Only Ferromagnetic Materials Have This Property

- Traditional Electromagnets Typically Have High Loss
- Remanent Operation Permits Continuous Measurement Without Applying Power Continuously



Additional Considerations

- Optimal system
  - Electrical energy used to create field
  - Field maintained with zero energy input
  - Magnetic energy recovered back to electrical energy

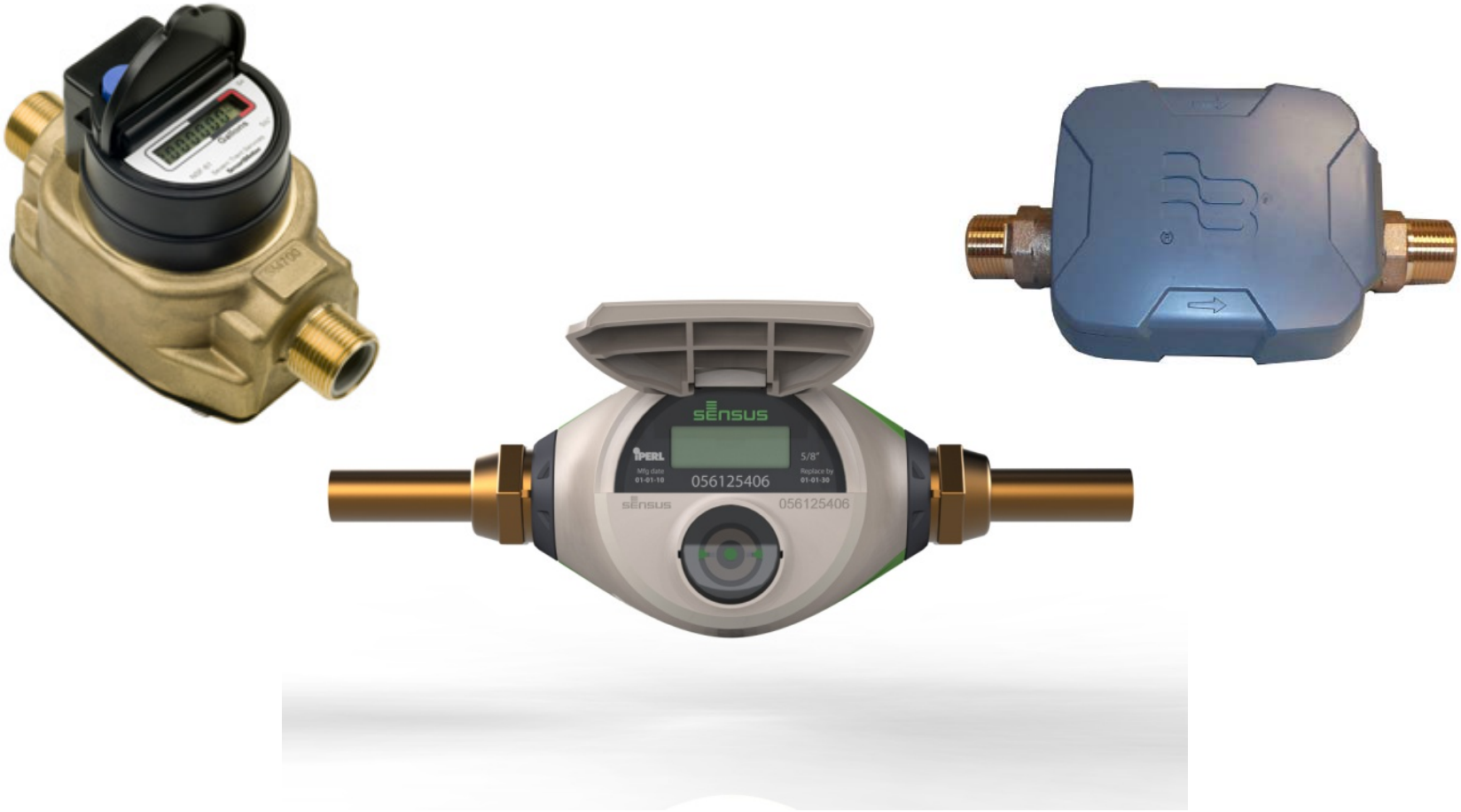
- "Remanent" magnetic system
  - Only uses energy to *switch* the field
  - Field Area is Relatively Small and Efficient
  - Electrodes are Very Low Noise

Low noise allows the field to be flipped less often, uses less power, and improves repeatability

Advanced Alarms

- Solid State Meters Deliver Advanced Features and Alarms:
  - On-Board Data Logging at Register
  - High Resolution Leak Alarms
  - Backflow Alarms
  - Empty Pipe Alarms (Tamper or Water Line Break)
  - Flow Rate Logging

Solid State Meter Performance



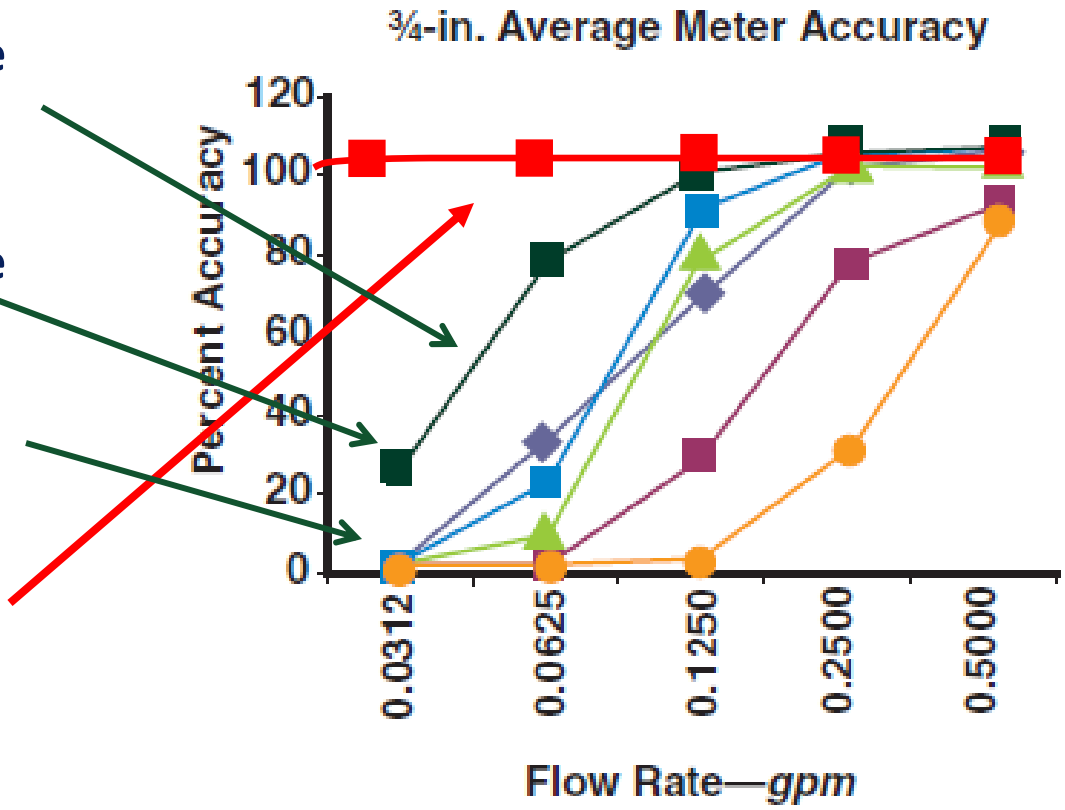
Remember The ¾” Mechanical Meter Test Data?

No Meters Registered More than 50% at 0.05 GPM

No Meters Registered More than 25% at 0.03 GPM

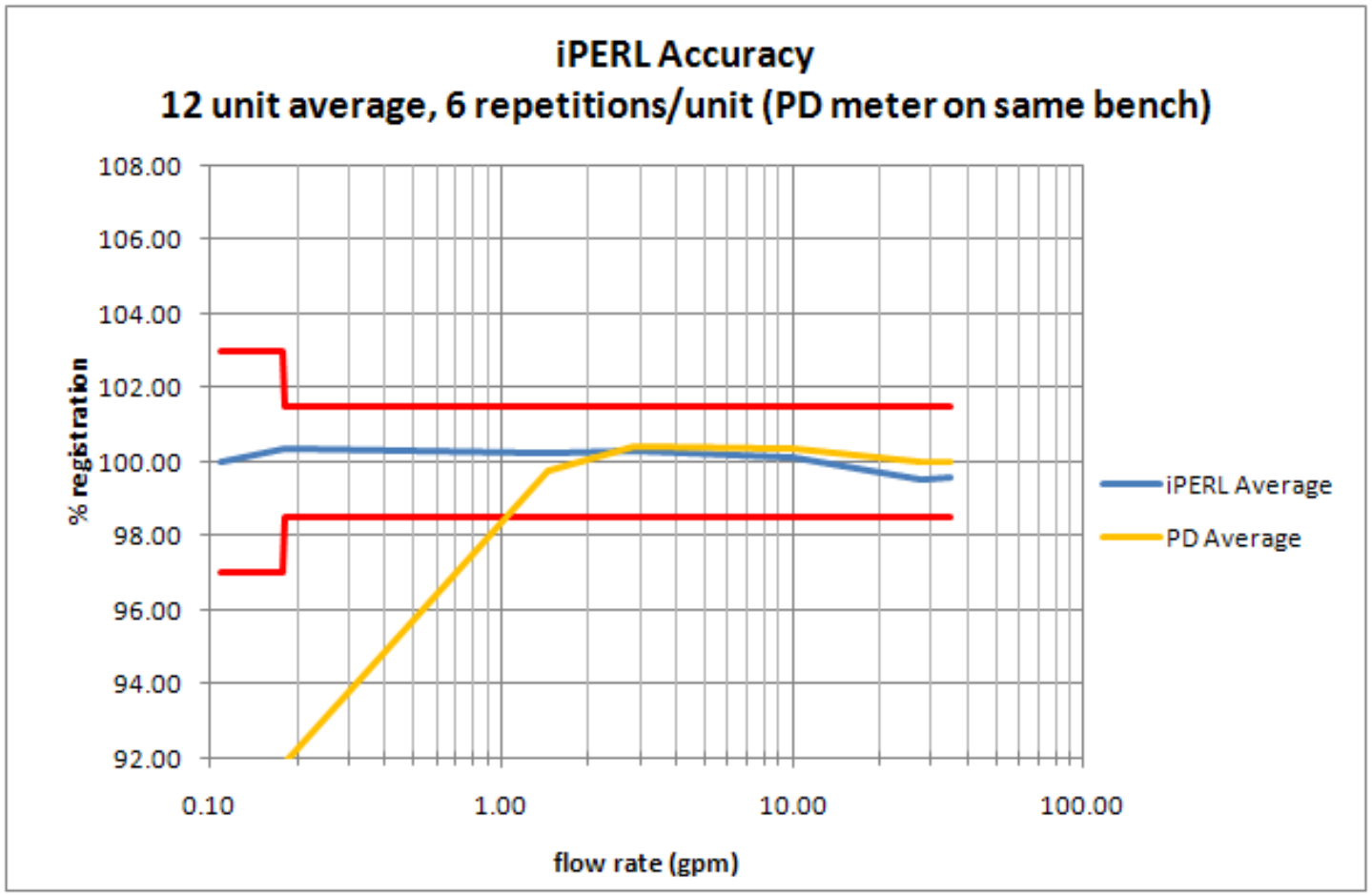
Most Registered 0% at 0.03 GPM

Solid State Meters Can Measure Much Lower Flows at Very High Accuracy



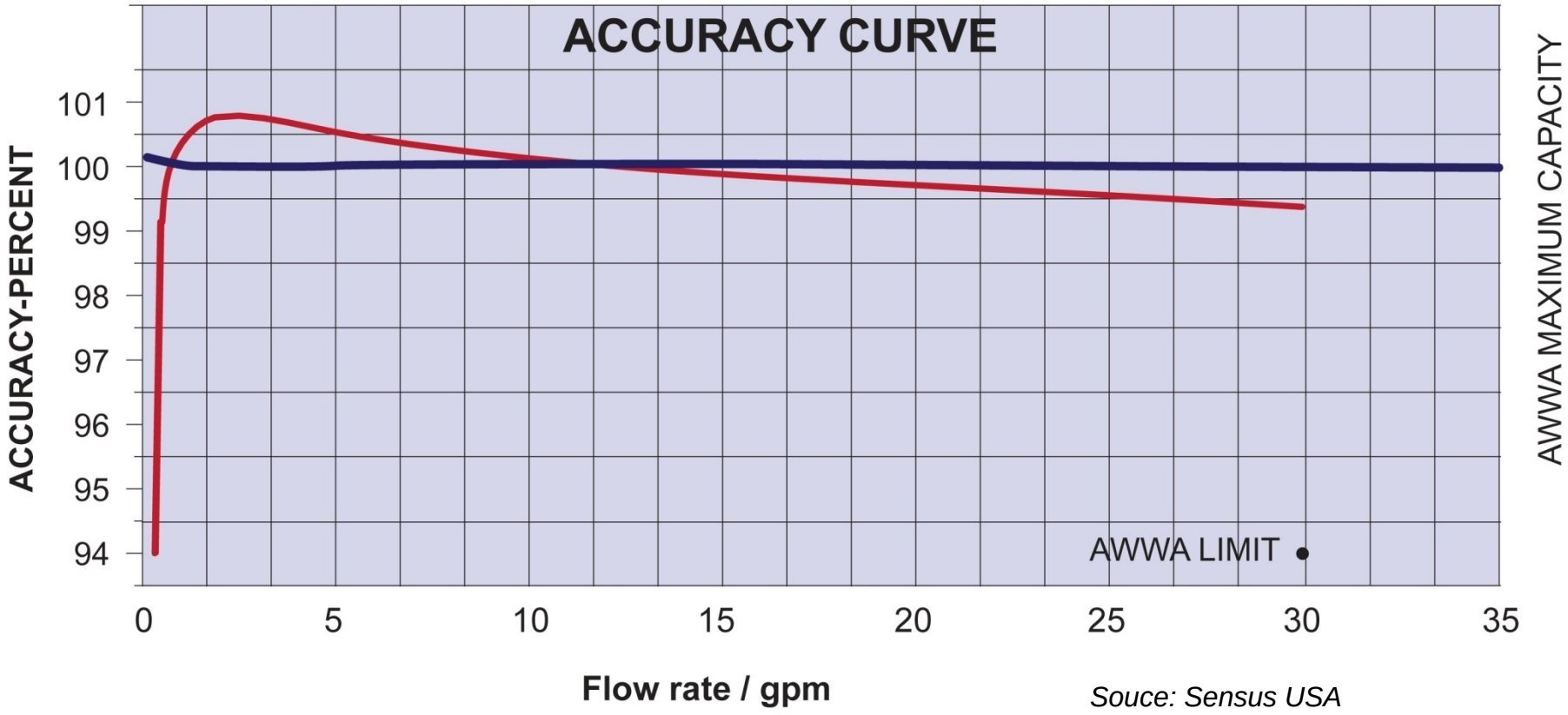
Graph Source: ***Apparent Losses Caused By Meter Inaccuracies at Ultralow Flows****, Richards et.al, AWWA Journal, June 2010*

Solid State Accuracy



Souce: Sensus USA

Accuracy Curve - Linearity

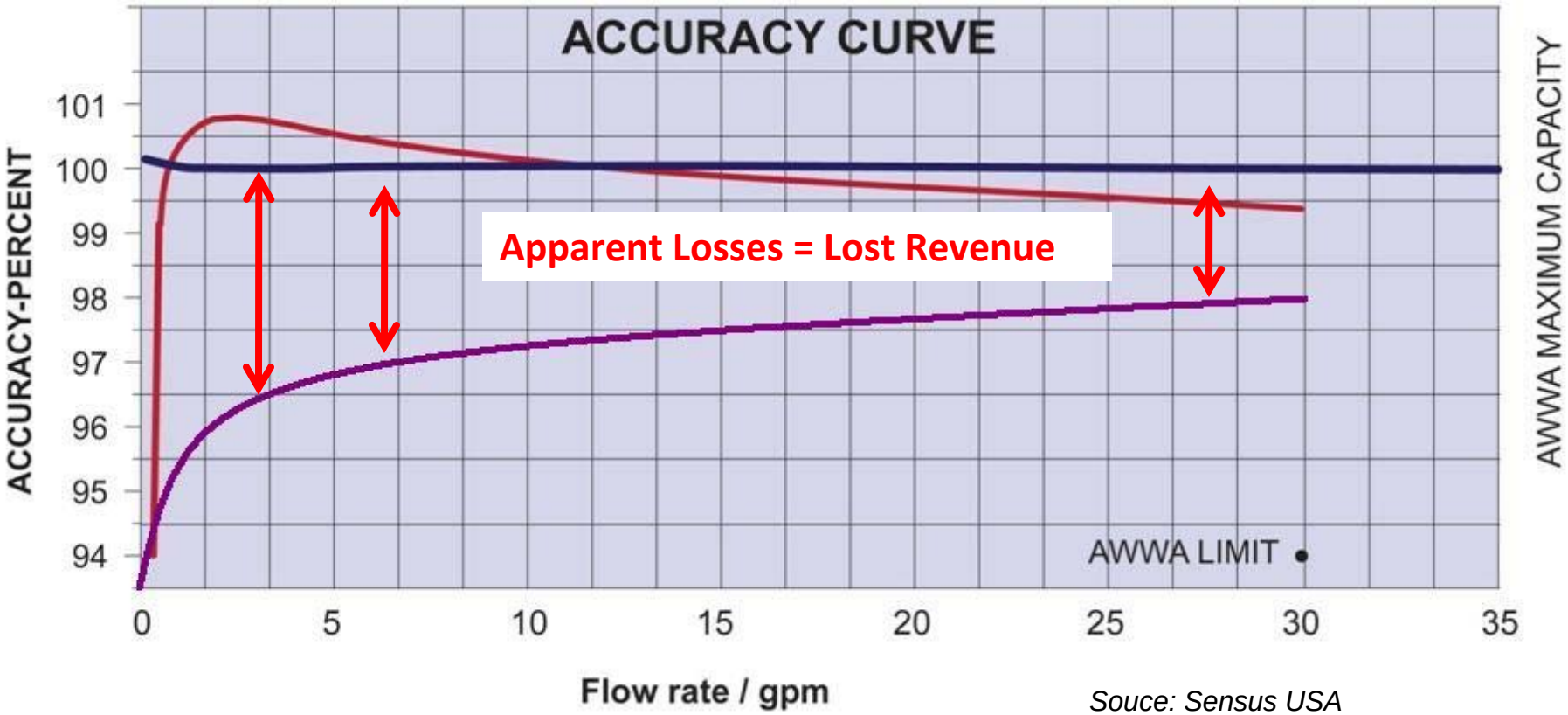


Souce: Sensus USA

Typical PD Meter

iPERL

Accuracy Curve - Longevity



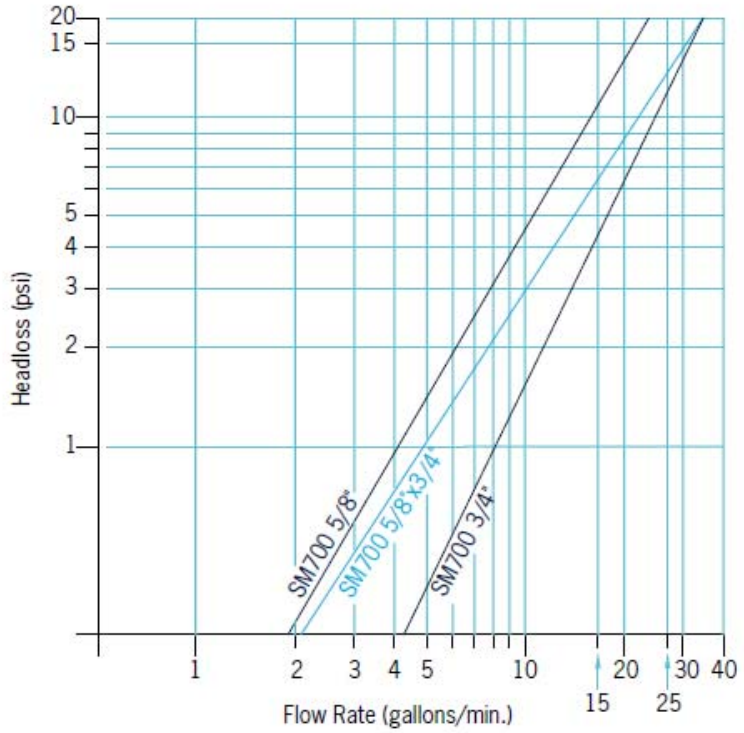
Souce: Sensus USA

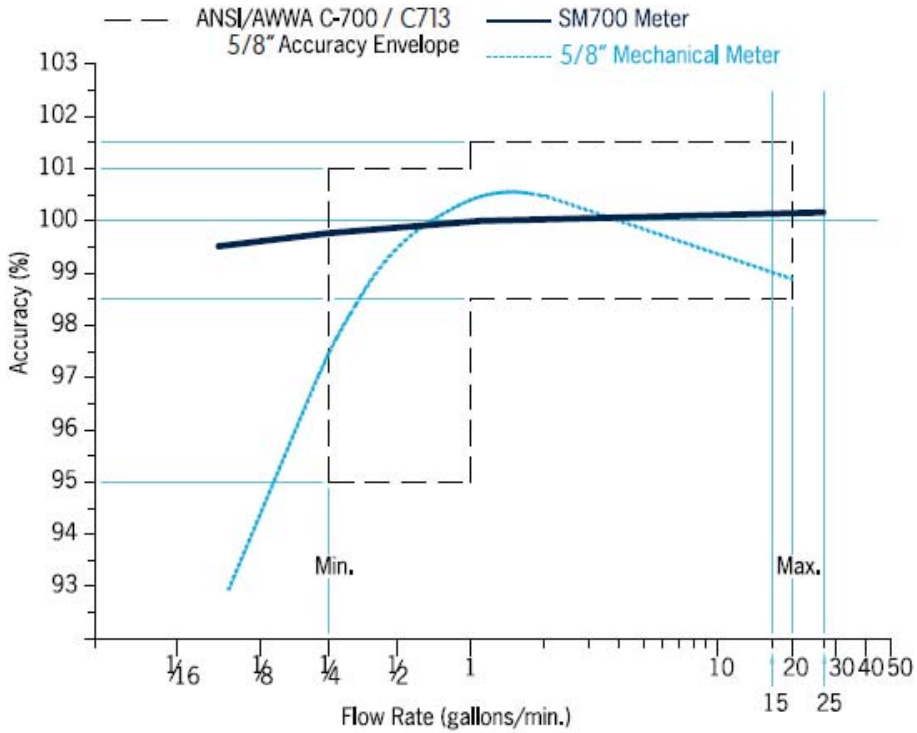
Typical PD Meter

iPERL

Typical 20 Year Old PD Meter

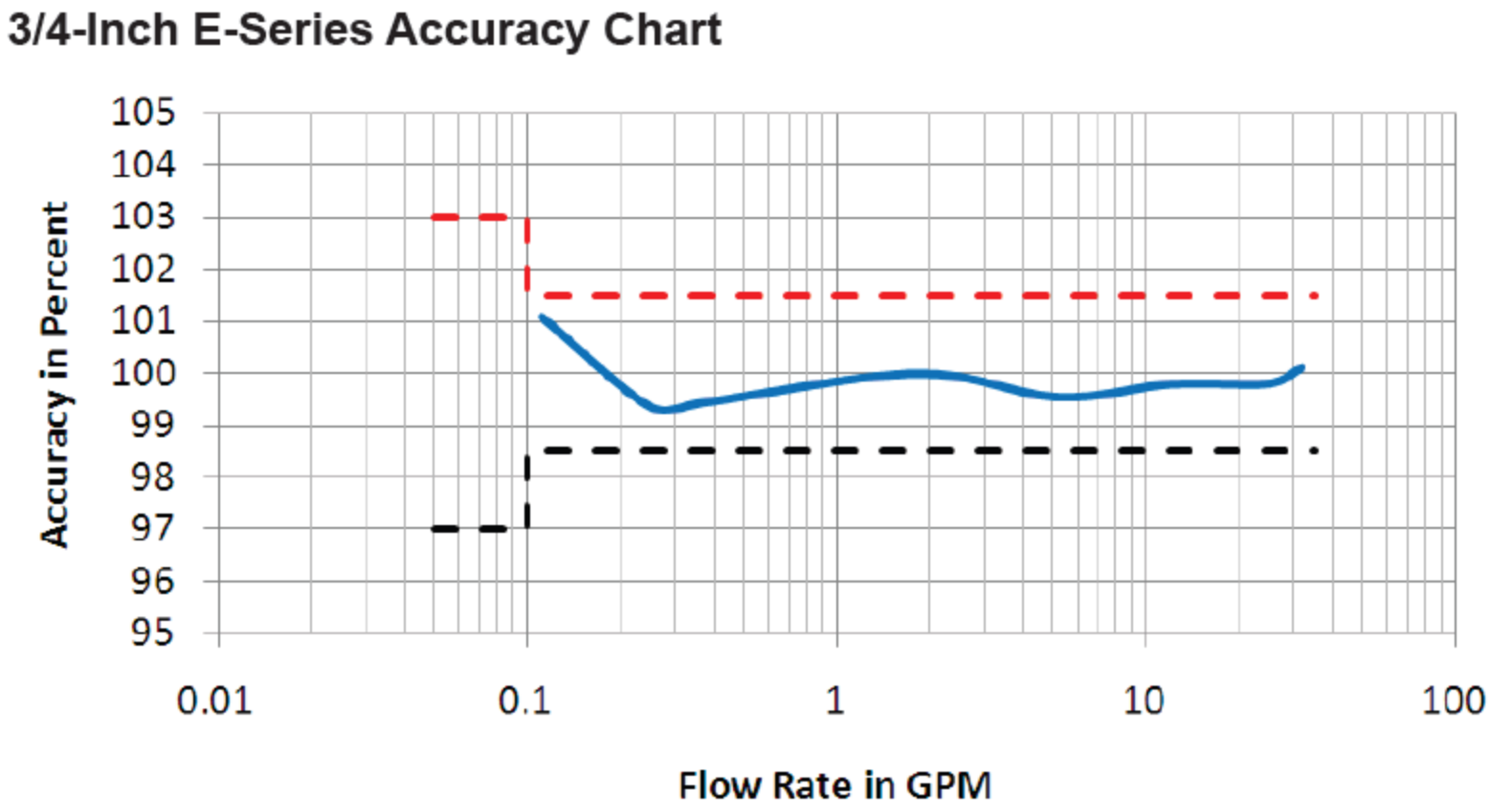
Elster SM 700 Head Loss and Accuracy





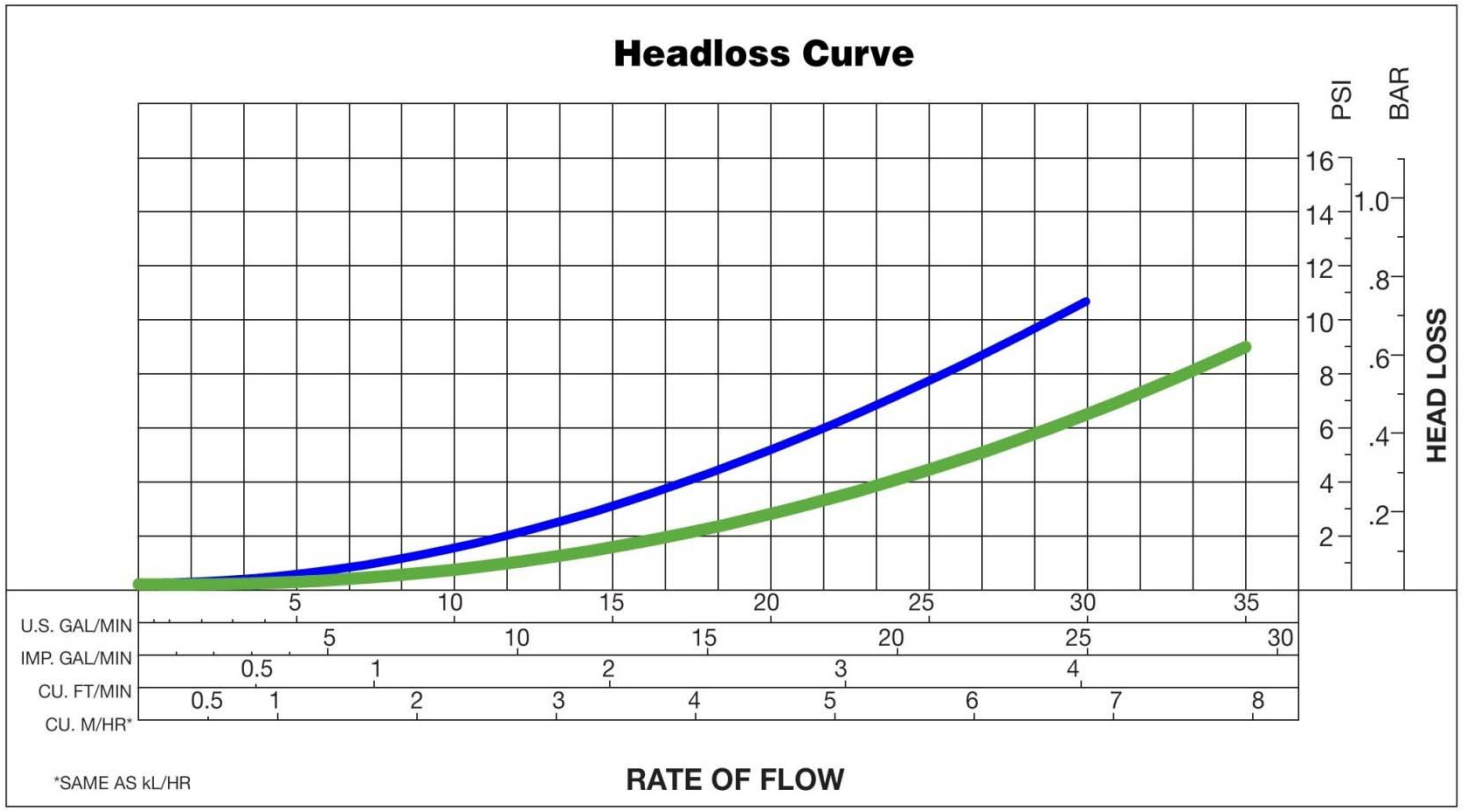
Source: Elster Metering

Badger E-Series 3/4” Accuracy



Source: Badger Meters

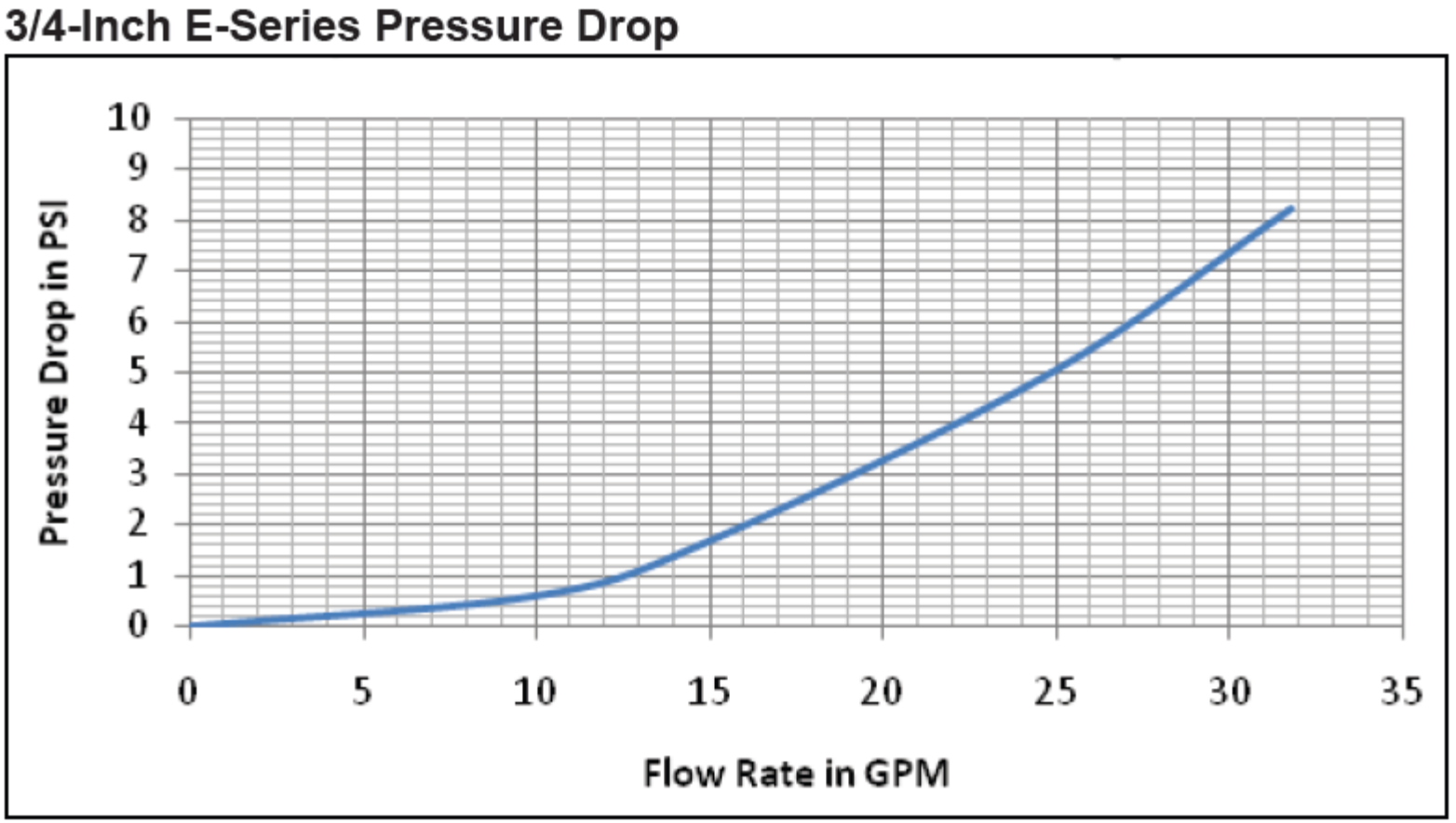
iPERL Head Loss Curve



Typical PD Meter

iPERL

E-Series Head Loss Curve



Source: Badger Meters

Utah Water Research Laboratory Study

Conclusions:

"Reduction of apparent losses caused by meter inaccuracies at low flows can result in substantial increases in revenue for a utility."

"Additionally, increased meter accuracy will allow for more equitable billing of customers."

Richards, Johnson and Barfuss; Utah Water Research Laboratory

Conservation and Revenue

- Solid State Technologies Offer a Win-Win for Utilities, Consumers, and the Environment
  - They Can Reduce Apparent Losses From Meters, Allowing Utilities to Bill for More of the Water Actually Delivered
  - They Can Help Eliminate the Smallest Leaks
  - They Can Pay for Themselves in a Few Years
  - They Deliver More Information Than Ever Before
  - Environmentally Friendly Composition

Conclusions

- Mechanical Meters Are Still a Viable Solution
  - They Have Served Us Well for Over 100 Years
- New Technologies *Available Today* Offer Compelling Financial and Ecological Benefits
- They Compliment AMI System Deployments but Offer Many Benefits Independent of AMI
- Utilities Should Explore and Understand the Potential of These Meter Technologies

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